

This is the annual adjustment that LECs are required to make to their rates based on anticipated increases in productivity as a result of more advanced technology or other efficiency-enhancing factors. The higher the "X-factor" is set, the more efficient LECs are expected to become, and the lower rates should be as a result (since rates are based on costs). The Commission has conceded that its latest *Price Cap Order* sets the X-Factor well above what is "reasonable."¹⁴⁷ As a result, incumbent local exchange carriers have a disincentive to upgrade to advanced technology that would increase the level of the X-factor even further, since it would only reduce the rates that such companies could charge for the new advanced services they developed.

Finally, regulators have used their ratemaking authority to load costs on to certain services and not others. These kind of subsidy programs have the effect of encouraging carriers to enter markets and provide services based on artificial regulatory incentives rather than true economic incentives. In 1983, for example, the Commission exempted Enhanced Service Providers (ESPs) from paying access charges for their use of the local telephone network. In 1987, the Commission recognized that this distinction made little sense since ESPs use precisely the same local lines as are used for voice calls, and indeed use them (on a per-customer basis) substantially more.¹⁴⁸ The absence of access charges for some providers, but not others, creates an uneven playing field that is a disincentive for many kinds of potential competitive entrants.

¹⁴⁷ The FCC set the X-factor at 6.5 percent, even though historical productivity gains (the measure the Commission admittedly considers most reliable) have never showed productivity gains even approaching 6.5 percent. *See Price Cap Order*, para. 137 (highest five year average 6.1 percent); *see also id.*, para. 139 ("there is no extended time period over which the measured [productivity gains] remained substantially above 6 percent.") According to the FCC's own studies, the most recent five-year average was a mere 5.2 percent, as was the overall average for the past ten years. *Price Cap Order* @ para.137. By the Commission's own admission, the 6.5 percent offset is outside the range of reasonableness. The lower bound of reasonableness, the Commission concluded, was 5.2 percent. The "upper bound" of reasonableness was around 6.1 percent based on the Commission's data, or "6.3 percent if the FCC included AT&T's admittedly inflated estimates in the analysis.

¹⁴⁸ Notice of Proposed Rulemaking, *Amendments of Part 69 of the Commission's Rules relating to Enhanced Services Providers*, 2 FCC Rcd 4305 (1987).

Unbundling and Resale Rules: Under the Act, incumbent LECs are required to unbundle and sell to competitors whatever new capabilities and services incumbent local exchange carriers add to their networks.¹⁴⁹ The Act also grants the states the authority to set the prices for new network elements "based on the costs of providing" them.¹⁵⁰ As currently formulated, the pricing standards developed in virtually all states require local exchange carriers to give competitors access to network elements at prices at or near the incremental cost of providing them, and below the actual book cost including capital and depreciation.

These pricing standards create strong disincentives for incumbent local exchange carriers to invest. On the one hand, if incumbent LECs make large investments in new facilities and services, competitors will be able to take these elements at cost.¹⁵¹ On the other hand, if no competitors take these elements, the investment made by the incumbent LEC will be largely unrecoverable. Under price cap regulation, local exchange carriers are not entitled to automatically recover their costs, but must bear the full risk of their investments.¹⁵²

The unbundling rules also give competitors very little incentive to deploy broadband technology themselves. Competitors may buy unbundled pieces of the existing network below cost – as well as any successful new technologies at cost – with substantially less risk of losing

¹⁴⁹ 47 U.S.C. '251. The Commission has recently proposed to extend its unbundling rules to permit competitive information service providers to obtain unbundled network elements. *See Computer III Further Remand Proceedings*, Further Notice of Proposed Rulemaking, CC Dkt. Nos. 95-20, 98-10 at 94-96 (released Jan. 30, 1998).

¹⁵⁰ 47 U.S.C. 251(d).

¹⁵¹ Even then-Chairman of the FCC Reed Hundt noted that the unbundling rules do not "create economic incentives for the telephone companies that are proprietors of parts of the Internet, particularly the local loop . . . to upgrade those particular businesses." *See* FCC Drafting Rule Proposal to Address ILECs' Innovation Concerns, Communications Today, Sept. 17, 1997.

¹⁵² *See Illinois Public Telecommunications Ass'n v. FCC*, 117 F.3d 555, 570 (1997) (since price caps went into effect, "investors rather than ratepayers have borne the risk of loss" on telephone company investments).

unsuccessful investments. No economically rational new competitor will build anything that it can buy below cost.

Finally, the resale obligations of the Act require that carriers that develop new services provide these services to their competitors at wholesale rates.¹⁵³ This places incumbent LECs in the position of being unable to differentiate their broadband services from those of their competitors. As with the unbundling requirements, the resale requirements force incumbent LECs to bear the entire risk of their investments in broadband services, without providing any assurance that customers (or competitors) will take the new service.

Cable operators are also subject to burdensome unbundling regulations of sorts. Cable operators must devote large portions of their systems' capacity to other programmers.¹⁵⁴ Cable is required to devote one third of its channels to carry local TV stations, and is required to set aside additional channels for lease and "public access." Under these rules, the more capacity that a cable operator builds, the more it must give away to others. As a result, cable operators' incentives to expand their systems are more limited than they might otherwise be.

Many of these pseudo-carriage obligations also apply to new entrants that seek to compete against incumbent cable operators. For example, the Act establishes a new regulatory regime for providing video services – an Open Video System (OVS).¹⁵⁵ The Commission subjects OVS operators to many of the same obligations that cable operators face regarding the carriage of local broadcast signals. The Act directs the Commission to extend its rules concerning sports exclusivity,

¹⁵³ 47 USC ' 251(c)(4).

¹⁵⁴ See, e.g., 47 U.S.C. '531 (requiring cable operators to carry channels for public, educational or government use); 47 U.S.C. '532 (requiring carriage of channels for commercial use); 47 U.S.C. '535 (requiring carriage of local commercial television signals); 47 U.S.C. '535 (requiring carriage of noncommercial educational television).

¹⁵⁵ See 47 U.S.C. ' 571(a)(4).

network nonduplication, and syndicated exclusivity to operators of open systems. OVS operators are also required to comply with the obligations regarding "must-carry" of broadcast stations;¹⁵⁶ leased-access channels for commercial use;¹⁵⁷ carriage of channels for public, educational or governmental use,¹⁵⁸ and carriage of noncommercial educational channels.¹⁵⁹

Other Regulatory Impediments: The principal providers of broadband services today are large integrated carriers that operate national or international networks. For example, the major Internet backbones are controlled by the long-distance carriers, WorldCom, MCI, AT&T and Sprint.

Incumbent LECs are generally prohibited from providing interLATA services over their networks.¹⁶⁰ Yet most of the services that use advanced broadband facilities are inherently interLATA in nature. Accordingly, this ban effectively extends to most types of "information services," including all types of Internet services except local Internet access.¹⁶¹ ISDN and ADSL services, for example, are rarely used to make local telephone calls, but principally to send and receive data on the Internet, corporate intranets, or on-line services like CompuServe and America Online. But since these data transmissions travel across LATA boundaries, incumbent LECs are

¹⁵⁶ 47 U.S.C. ' 534

¹⁵⁷ 47 U.S.C. ' 532.

¹⁵⁸ 47 U.S.C. ' 531.

¹⁵⁹ 47 U.S.C. ' 535.

¹⁶⁰ See 47 U.S.C. ' 271(b)(1).

¹⁶¹ The FCC has held that, for purposes of ' 271(b)(1), "interLATA services" includes "interLATA information services." *Implementation of the Non-Accounting Safeguards of Sections 271 and 272 of the Communications Act of 1934, as Amended*, First Report & Order & Further Notice of Proposed Rulemaking, FCC 96-149, & 55 (rel. Dec. 24, 1996).

restricted in their ability to provide online or Internet information services,¹⁶² and reducing their incentive to invest in the facilities that are used to provide local access to them.

The interLATA restriction likewise bars incumbent LECs from building Internet backbones or any other kind of regional or national broadband network. Internet backbones are, by definition, regional or national in scope. They necessarily cross LATA boundaries. It is regulatory restrictions – and not economics – that keep the incumbent LECs from participating in these markets.

The interLATA restriction also has been interpreted to impose equal access obligations on incumbent LECs' local Internet access services.¹⁶³ At present, incumbent LECs offering Internet access cannot provide or resell interLATA Internet carriage. Rather, an incumbent LEC typically asks its Internet customers to select a preferred interLATA Internet provider, in much the same way as the customer selects an interexchange carrier by way of a PIC. Other Internet Service Providers, however, are permitted to bundle local Internet access with interLATA Internet carriage. It is not surprising that most are doing so; it is a far more efficient arrangement as it enables the ISP to purchase interLATA carriage in bulk, often at steep discounts.

Additional economies of scope arise from the fact that facilities or employees can simultaneously perform tasks that are helpful to a firm's efforts in more than one activity. Being able to take advantage of these economies of scope is often an incentive for firms to make large incentives. At present, incumbent LECs face a wide array of separate affiliate requirements that prevent many economies of scope from being realized.

¹⁶² The most that Bell companies are permitted to do is provide Aa service that permits a customer that is located in one LATA to retrieve stored information from, or file information for storage in, information storage facilities of such company that are located in another LATA, 47 U.S.C. '271(g)(4).

¹⁶³ See *Bell Atlantic Tel. Cos. Offer of Comparably Efficient Interconnection to Providers of Internet Access Services*, 11 FCC R 6919 (1996).

Under the Act, even after interLATA relief, Bell companies must provide all interLATA services – including interLATA information services – through separate subsidiaries.¹⁶⁴ This requirement significantly increases the costs of designing and operating a broadband network by requiring the deployment of duplicative operations and personnel, and eliminating many of the efficiencies of integrated operations. Non-BOC incumbent local exchange carriers also must provide long-distance services through separate affiliates.¹⁶⁵ All incumbent LECs (except for rural telephone companies) are required to provide all in-region broadband wireless services through a separate affiliate.¹⁶⁶

C. Removing barriers to broadband investment can be accomplished through a containment policy for regulation

PFF's research indicates that the investment for broadband infrastructures, independent of the technology, will only be forthcoming in a "reasonable and timely fashion" if there is a containment policy for regulation. This containment policy should ensure that "advanced telecommunications services," which can be defined as all presently unregulated packet based services, should be free from regulation.

In essence this proposal distinguishes traditional "telephone exchange service" or "exchange service" from "advanced telecommunications services" based on the format and the data rate over the wired local loop: packet based services having data rates of 1.544 Mb/s or above in the downstream direction (central office/point of presence towards the subscriber) and 384 kb/s or

¹⁶⁴ See 47 U.S.C. ' 272; First Report and Order and Further Notice of Proposed Rulemaking, *Implementation of the Non-Accounting Safeguards of Sections 271 and 272*, CC Docket No. 96-149, FCC 96-489 (rel. Dec. 24, 1996).

¹⁶⁵ See 47 CFR ' 64.1903.

¹⁶⁶ See Report and Order, *Amendment of the Commission's Rules to Establish Competitive Service Safeguards for Local Exchange Carrier Provision of Commercial Mobile Radio Services*, WT Dkt. No. 96-162 (released Oct. 3, 1997); 47 C.F.R. ' 20.20.

above in the upstream direction (subscriber towards central office/point of presence). Packet based services are defined as those services in which information (of any type) is routed based on information contained within a header/addressing field as opposed to a position in a time, as occurs in circuit switched networks. Existing Title II services which meet these criteria (e.g. Frame Relay) would remain regulated under Title II.

The interconnection, unbundling and resale requirements of the Act in the local loop portion of the network would be met for Title II services via separation of packet based vs. narrowband circuit switched services at the twisted wire pair level (frequency unbundling) or at a switch/terminal which permits separation of packet based information from circuit switched information.

Pure price cap regulation – applied to regulated services only – must be adopted both at the Federal and State level in order to permit the use of integrated transport systems which will provide carriers with the ability to achieve economies of scope.

PFF's research indicates that this delineation would allow the Commission to separate the historically regulated telecommunications equipment and services from advanced and emerging equipment and protocols which will provide the basis for an advanced telecommunications infrastructure. Failure to boldly deregulate advanced telecommunications services and attempts to adapt the complex system of telephone service regulation with its corresponding web of cross-subsidies will only serve to severely delay the deployment of advanced telecommunications capabilities to all Americans. In order to meet the statutory requirements of Section 706 the Commission must deregulate, not further regulate, advanced telecommunications services.

D. Universal service issues

Taking the bold step of delineating traditionally regulated services from advanced telecommunications services and forbearing from regulating advanced services with the knowledge that the majority of services (including traditional voice services) may eventually migrate to unregulated platforms raises the issue of universal service funding. Specifically, the proposal forces one to consider how the Commission can knowingly take steps that might limit the funding base for the existing universal service program. However, the situation is not as dire as it might seem, given the high penetration rate of telephone services (93.9 % of US residences) and the fact that the migration of voice services from circuit switched to the proposed unregulated packet based networks will take upwards of a decade. The present reform of the universal service system will need to continue, but should be isolated from advanced telecommunications services.

What is clearly required for advanced telecommunications services is examination of the penetration rates for advanced telecommunications services which will be achieved through market forces, as well as the penetration rates over time which form the basis for sound public policy, minimize “redlining” and support rural areas. Once the deployment of advanced telecommunications capability begins *en masse*, it will be possible for the Commission to determine what explicit mechanisms can be used, if necessary, to ensure that “all Americans” have access to those services.

The present path of the Commission will lead to the mixing of narrowband subsidization policies with broadband issues, and can only serve to further promulgate a system in which prices for local loop services do not way reflect costs. Should this system be applied in any way to advanced services it will only serve to deter investment and slow competition.

VI. CONCLUSIONS

The NOI which initiated this proceeding asks a number of profound questions, but none more important than those contained in paragraph 80.

Looking into the future, we ask what, if any, system of regulation might best fit the market for advanced telecommunications capability. Enacting such a system might require major amendments to the Act. For example, it is reasonable to question a policy of regulating several competitors in a market differently . . . [W]e ask parties to consider the Internet industry as a model of what a maturing market for advanced telecommunications capability and advanced services might be.

PFF's research suggests that the Internet model is precisely the correct one for the market for advanced telecommunications services. However, the Commission does not have to, and indeed must not, await the passage of new legislation before embarking on the path towards implementing such a system.

As this filing shows, developments in the broadband digital marketplace are occurring at breakneck speed. Cable modem subscribership is growing at triple-digit annual rates; demand for broadband services is growing, arguably, even faster. Steps taken in the direction of additional regulation are difficult to undo, and, indeed, set in place their own "feedback loops" – more regulation begets still more regulation. If this cycle is permitted to continue, achieving the Internet model will become far more difficult, if not impossible. Thus, while the Commission may well need new direction from Congress before fully implementing the Internet model suggested in the NOI, it can take steps today to prevent the further spread of regulation.

A. Intermodal competition, not regulation, is the key to encouraging the deployment of advanced telecommunications capability

The wide range of technologies which will be used to support advanced telecommunications services, coupled with the demand for bandwidth both at the business and the residential level will

drive the deployment of infrastructures for these services – but only if left to grow unregulated.

Once the path of regulation, as opposed to deregulation, is chosen, it will be difficult to escape the cycle of regulatory rulemaking, litigation, and regulatory reform. Intermodal competition, in particular the competition which could occur between cable operators and LECs, can provide the basis for the deployment of advanced telecommunications capability.

B. Harmonization of public policy towards advanced telecommunications capability networks can only be accomplished through deregulation

1. The dangers of “harmonization” through taking a Title II approach to packet networks and Title VI networks carrying data.

The NPRM associated with this NOI, which proposes separate subsidiaries for data services, is one step towards “harmonization through regulation” in which data services delivered by telephone companies are regulated either directly (as in the case of incumbent LECs) or indirectly by forcing separate subsidiary requirements on incumbent LECs. Embarking on such a path will necessitate reexamination of all of the existing rules regarding data and network operators including Title VI cable operators.¹⁶⁷

Another example of how “harmonization through regulation” is bound to occur if the Commission does not adopt a containment policy towards regulation is in the area of Customer Premises Equipment (“CPE”) and network interfaces on the subscriber side. Part 68 definitions for the narrowband telephone interface have been successful in creating a competitive market for telephone CPE, but it is frequently forgotten that the technology which enabled this interface to be developed was based on decades of private investment and what was essentially a closed

¹⁶⁷ The challenge now facing the Commission with respect to regulating data services offered by Title VI providers is discussed in length in the paper by Barbara Esbin, *Internet Over Cable: Defining the Future in Terms of the Past*, OPP Working Paper No. 30 (August 1998).

architecture. Extending the methodology of Part 68 to the advanced telecommunications services industry which has not yet deployed significant amounts of equipment will only have a chilling effect on making new services available to all Americans. The NPRM¹⁶⁸ raises the issues of standards for the advanced telecommunications services interfaces and a “broadband” part 68. The fact that incumbent LECs could choose to offer advanced telecommunications services as a regulated Title II common carrier will necessitate the Commission’s involvement in defining advanced services interfaces and may lead to intrusive regulation in this area.

2. Bundling of services and CPE must be permitted to achieve economies of scope.

One of the powerful aspects of intermodal competition is that it provides subscribers with a choice of services including the end-user or Customer Premises Equipment. Initially, these services will not be such that “mix and match” between any two elements is possible, but due to the nature of the Internet and the availability of alternate technologies interoperability is not necessary. Cable modems may only allow connection to the Internet via a single ISP but provide high speed connectivity to the Internet with no restrictions. Telephone company (incumbent or competitive LEC) provided data services offer an alternative to cable, as will wireless service providers.

Because of the technologically advanced nature of these networks, service providers will base their deployments on architectures which have interfaces in the residence that may be specific to their equipment, but which end in standards-based interfaces (e.g. Ethernet or Universal Serial Bus) and provide connectivity with any number of devices in the residence.

Bundling of services and CPE should be seen less as a requirement for regulation and more as an incentive for investment. The wireless industry, where bundling of services and CPE is the

¹⁶⁸ NPRM paras. 154-155, 163.

industry norm, has not been harmed by these practices. The Commission should pay close attention to its successes in deregulation and apply these lessons to advanced telecommunications services.

C. Anti-trust vigilance, not prophylactic regulation, is the key to encouraging deployment of advanced telecommunications capability

In the combined statement of Commissioner Michael K. Powell on the Order/NPRM,¹⁶⁹ the Commissioner accurately points out that communications policy has historically emphasized prospective, prophylactic regulation which tends to stifle innovation and innovation and impede the beneficial operation of market forces. We note that in addition to stifling innovation and impeding market forces, regulation is self-perpetuating. Bold steps must be taken in order to break the vicious cycle of regulation.

Such a step could be taken by the Commission by defining advanced telecommunications capability in a manner that precludes its regulation, and exempts such services from any such regulation under Title II. Providing such a definition would allow incumbent LECs to provide advanced services on an integrated basis without being subject to interconnection, unbundling, and wholesale requirements, and would allow them to obtain the economies of scope needed to provide advanced services in a profitable manner at high penetration rates. There are valid concerns with respect to the market power of incumbent LECs, but such concerns should be dealt with as anti-trust issues, rather than removing incentives to deploy advanced networks and services.

Excluding advanced telecommunications capability from regulation would not undermine the Commission's authority or ability to ensure that collocation and unbundling of twisted wire pairs is accomplished in a manner which allows competitive LECs to enter the market. Aggressive

¹⁶⁹ NRPM, Separate Statement of Commissioner Michael K. Powell.

and timely enforcement of this aspect of the Act would ensure competition for narrowband services as well as the entry of competitive LECs into advanced services.

By providing a deregulated environment for advanced telecommunications services, the Commission can encourage investment by the groups able to provide an infrastructure for advanced telecommunications services: incumbent and competitive Local Exchange Carriers, cable operators, and wireless service providers. Any regulation which significantly stifles investment from any one of these sectors threatens the competitive marketplace and will lead to a slow, highly regulated rollout of advanced services which may have grave economic consequences.

APPENDIX A: A PROPOSAL FOR PACKET BASED DEFINITION OF BROADBAND SERVICES AND CONTAINMENT OF REGULATION

Although there are many details and nuances to the technology surrounding the Internet, there exists a clear distinction between the circuit switched technology on which the telephone industry has been built, and the packet based system upon which the Internet is based. This distinction can be used to segregate the historically heavily regulated circuit switched telephone network from emerging packet based networks, which can subsequently be left unregulated to allow unbridled growth.

It is not a trivial task to separate technologies and establish the appropriate regulatory (or perhaps “unregulatory”) mechanisms for insuring that the historical circuit switched network is appropriately deregulated while isolating the packet based services. In addition to the basic technical matter of distinguishing the technologies, there are complex issues related to the of unbundling of twisted wire pairs which can simultaneously transport circuit switched narrowband services and packet based broadband services, and avoiding inappropriate cross-subsidization of the packet based network by revenues from the circuit switched network. In addition, many parts of the network will simultaneously carry circuit based services and packet services, or transport circuit based services encapsulated in packets or visa versa. The goal here is not to separate all network elements and services, but rather to allow deployment of new local loop packet services in an unregulated mode. The present regulation of circuit based networks, including those that are used to transport packets, does not have to be discarded entirely, and the slow and painful process of deregulation of those networks will continue separate from the deployment of packet based networks and services.

This proposal discusses how local loop packet based services can be isolated from the burdensome regulatory history associated with circuit switched services. This isolation or “containment” of regulation will enable deployment of advanced networks based on demand and permit true competition in the area of broadband networks. This proposal does not attempt to look at all of the network and backbone issues related to packet services and deregulation, but instead focuses on the technical definition of packet based services which would allow separation of packet and circuit switched services in the local loop and the data rates required to ensure that the network is indeed broadband.

Technical issues related to unbundling are discussed, and it is shown that narrowband services can be separated from packet based services on both twisted wire pair drops, as well as in integrated transport systems in which the circuit switched data may be carried in a packet or cell format through much of local loop. Finally, cost allocation issues are addressed, and it is proposed that pure price cap regulatory schemes will need to be applied to narrowband circuit switched services while simultaneously deregulating broadband packet based services in order to provide appropriate incentives to deploy technologically innovative solutions in the local loop.

This proposal does not suggest that the existing plans for deregulation of the narrowband network are unworkable nor that the careful monitoring of the unbundling of network elements of existing Local Exchange Carriers and their entry into the provisioning of long distance services is unnecessary, but suggests that a bolder deregulatory approach to the deployment of packet based services is required.

Overview of Packet Technology

In order to understand distinctions between packet based and circuit based technologies it is necessary to review the basics of circuit switched telecommunications systems. Although the use of human operators to establish connections between subscribers in the earliest telephone systems was already a type of circuit switching, it was the advent of the Strowager mechanical switch¹⁷⁰ which allowed for automated connections between subscribers based on the number dialed, and was the first instance of automated circuit switching.

In the initial analog telephone system, circuits were initially switched based on simply establishing a mechanical connection between subscribers. Later, Frequency Division Multiplexing (FDM) technology was used to aggregate calls in the long haul network, with each subscriber being assigned a bandwidth (in the form of a range of frequencies) within a frequency multiplex, and calls could be removed and added from the frequency multiplex. The advent of digital switching allowed for calls to be aggregated based on the concatenation of voice samples generated by digital sampling of the voice signal received at the central office. Digital switching, in which the binary representation of the voice signal is manipulated and individual bytes of information are routed to perform the switching, forms the basis of the existing telecommunications network in the US.

The sampling of the voice signal at a rate of 64 kb/s produces an acceptable quality signal, and in order to reconstruct the signal properly (without gaps in speech or excessive delay) the signal

¹⁷⁰ It is interesting to note that the invention of the mechanical telephone switch was motivated largely by economic, not technological reasons: Almon B. Strowger was a Kansas City, Missouri undertaker who found that all "new business" was being directed to his competitor. As it turns out, his competitor's wife was the telephone operator for the city and promptly routed all calls concerning new deaths to her husband. Strowager invented the telephone switch in 1889 to remedy this situation in by allowing subscribers to dial each other directly without operator intervention. The Strowager switch, also known as the two-motion, or step-by-step switch, was patented in 1881 and began to be deployed by the Bell System in 1918. As of 1978, 53% of the Bell System exchanges in service (serving over 23 million subscribers) used Strowager switching.

is transported through the telecommunications network as one byte of user information every 125 ms. In order to ensure that the information is transported at a constant rate, each call or circuit is reserved time, also known as a “time slot” in the network for signal transport.

The basis for telecommunications services in the US is illustrated in Fig. 1, which shows a DS-1 signal frame, composed of a framing bit followed by 24 channels of voice data, each channel composed of one byte of voice information (with some bits occasionally used for signaling). The resulting composite of 24 channels, each having one byte transmitted every 125 ms, plus the framing bit, is a signal of 1.544 Mb/s. Numerous other transmission rates and formats are possible, but all are fundamentally based on the concept of transmitting voice channels at a data rate of 64 kb/s with minimal delay.¹⁷¹ Additionally, the routing of the information is based upon the temporal location of the information: a subscriber calling from location A to location B may be assigned channel number 2, the second “time slot” in a DS-1 and thus all bytes appearing in channel 2 of a DS-1 signal from location A will be routed to location B.

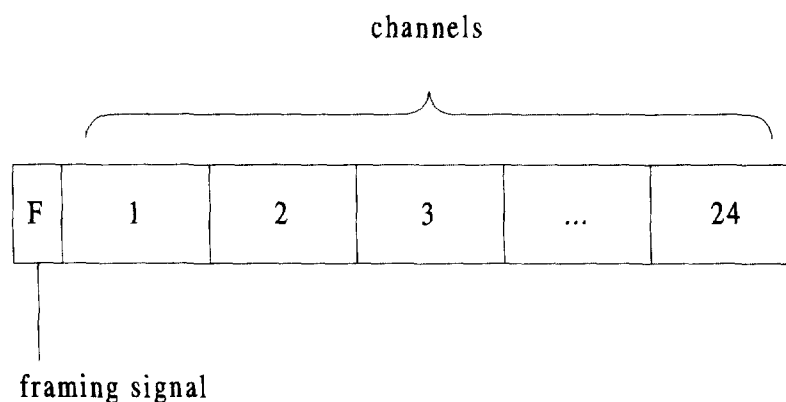


Figure 1. DS-1 circuit switched frame structure.

¹⁷¹ See Daniel Minoli, *Telecommunications Technology Handbook* (Artech House, Boston, 1991).

Why Packet Technology is Different From Circuit Switched Technology

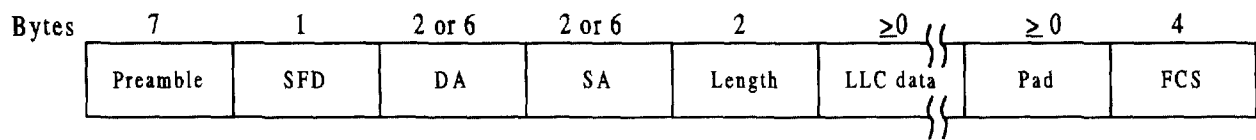
Packet technology has fundamentally arisen from the interconnection of computers, where large amounts of data needed to be sent between machines, with little regard for a constant (smooth) data rate, but with the need for rapid transport of large blocks of data. Hence the computer based packet protocols which have been developed traditionally work on the basis of seizing the bandwidth when available, and transporting large amounts of information in a short period of time. This simplification does not discount the large variants on the design parameters of Internetworking, Wide Area Network (WAN), Local Area Network (LAN) and Metropolitan Area Network (MAN) systems,¹⁷² but demonstrates that the development of packet based transport technology was motivated by interconnection of computers rather than subscribers using voice communications.

Figure 2 illustrates basic packet structures including (a) the IEEE 802.3 frame format, which is related to the original baseband Ethernet specification; (b) the Internet Protocol (IP) datagram,¹⁷³ which forms the basic unit for the transport of data across the Internet; and; (c) the Asynchronous Transport Mode (ATM) cell structure.¹⁷⁴

¹⁷² For a detailed discussion of networking standards and protocols see W. Stallings, *Networking Standards* (Addison-Wesley Publishing, Reading, Massachusetts, 1993).

¹⁷³ D.C. Comer, *Internetworking with TCP/IP* (Prentice Hall, Englewood Cliffs, NJ, 1995).

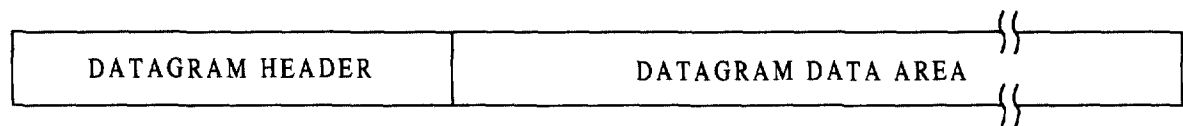
¹⁷⁴ M. de Prycker, *Asynchronous Transfer Mode* (Ellis Horwood, New York, 1993).



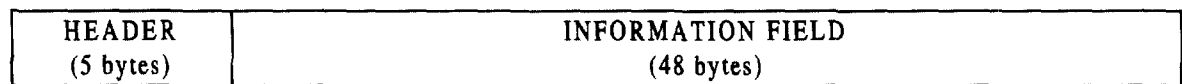
SFD = start-frame delimiter.
DA = destination address.

SA = source address.
FCS = frame-check sequence.

(a)



(b)



(c)

Figure 2. Frame structures for packet based communications including (a) IEEE 802.3 (Ethernet) frame structure; (b) TCP/IP datagram; and (c) ATM cell.

The common thread between these structures is that they are all designed to transport multiple bytes of data, and the routing of the data is dependent upon self-contained information at the front (header) of the packet or cell. In no way can this structure be confused with a circuit switched signal in which a “time slot” is reserved and the destination of the information is based on the temporal location of the information.

Within packet based systems there are numerous differences. As an example the packets of Fig. 2 (a) and (b) are variable in length, while the ATM cell in (c) is of fixed length. In addition, some packet based systems are connectionless (e.g. the Internet) and packets can take different

routes to the final destination, while ATM systems are connection oriented, meaning that cells are routed to their destination based on pre-established connections. There is considerable discussion as to whether IP or ATM will be the ultimate transport scheme, and hybrid schemes using IP routing to establish ATM connections are actively being explored.¹⁷⁵ It is unlikely that these disputes will be resolved in the near future, nor is it clear that any of the pure ATM, pure IP, or hybrid ATM/IP solutions will be adopted by the marketplace. It is entirely possible that new solutions will be developed which may not be based on the existing packet formats and protocols, but it is almost certain that they will be packet based, rather than circuit switched.

Voice services can be transported within all of these packet based systems, with the fundamental problem being one of delay: if one waits long enough to fill the packet or cell with voice samples, the time expended results in problems of noticeable echo or delay in the voice signal.¹⁷⁶ Additionally, the packet protocols have different (or in some cases lack) procedures for dealing with lost, delayed, or out-of-sequence packets. Voice services can be transported over any of the packet protocols, but with different levels of success, and it is fair to say that the quality generally does not match that of the existing circuit switched voice network.

¹⁷⁵ P.P. White, "ATM switching and IP routing integration: the next stage in Internet evolution?," *IEEE Communications Magazine*, vol. 36, no. 4, pp. 79-83 (April 1998).

¹⁷⁶ There are numerous types of delay and echo which can occur. Packetization delay, the time required to fill a packet with voice samples from a subscriber, can be significant, and when combined with coupling between the speaker apparatus and microphone at the subscriber location can result in annoying echo. Echo cancellation technology can be used to mitigate these effects. Transmission delay can also become an issue in some networks, and if the delay is appreciable (e.g. 500 ms or longer) the one-way delay in itself (absent echo) is perceivable and annoying. For a further discussion of delay in the local loop see C.A. Eldering and A. Martin Minguez, "System specification and requirements for Fiber in The Loop systems," in SPIE vol. 1786, *Fiber Networks for Voice, Video, and Multimedia Services*, pp. 156-165 (1992). One-way delay and user perception of such delays is discussed in N. Kitawaki and K. Itoh, "Pure delay effects on speech quality in telecommunications," *IEEE J. on Selected Areas in Communications*, vol. 9, no. 4, pp. 586-593 (May 1991).

This is not to say that these problems cannot be overcome: in fact it is likely that packet based technology will ultimately be a replacement for circuit switched technology. However, there are numerous technological hurdles to be overcome, and a fair amount of time will pass before packet technology becomes the predominant transport mechanism for traditional voice services. Given the embedded base of circuit switched technology for voice services, it is likely to be several decades before the majority of voice traffic migrates to packet based infrastructures.

Deregulating Packet-Switched Technologies

Given that distinctions can be made between the circuit switched and packet networks, one approach to ensuring rapid and unencumbered growth of packet based services is to eliminate regulation of the packet based network.

In the following discussion the concept of service separation rather than network separation is used because it is the *packet transport service*, or “broadband packet pipe” which is being distinguished from the circuit switched services. The end service application being provided over the packet network is inconsequential – once the packet based transport service is deregulated any applications which utilize the broadband packet pipe are deregulated- regardless of the application. This situation is quite different from the historical circuit switched network, where the service and network were indistinguishable. The initial phone network was only used for voice transport, and was a private network during its initial stages of deployment. Subscribers did not have the ability to separate the service from the transport. Packet based transport, and in particular the Internet Protocol (“IP”), is a public standard upon which a multitude of applications have been built, and in which applications can be run independent of the specifics of the physical and logical layers of the

network.¹⁷⁷ The interfaces for the packet based transport services are defined by public protocols (e.g. IP) and standard physical interfaces (e.g. Ethernet) and although it is likely that these protocols and interfaces will evolve or be replaced by new ones, there is no doubt that the tremendous advantages (network externalities) generated by global interconnectivity will ensure that the ensuing protocols and standards will be open rather than proprietary.

Despite the significant differences between the telephone network and the Internet, critics will rapidly point out that a) the success and growth of the Internet was based upon the use of the extensive and heavily regulated switched telephone network, and b) deregulating broadband packet based services will result in private networks and new broadband monopolies in the local loop. While point a) is certainly true, future growth of the Internet will depend heavily on the deployment of new packet based infrastructure, both backbone and local loop, since the existing narrowband infrastructure is entirely inadequate for high-speed services. As for the possibility of private broadband networks and local loop monopolies, it is clear that extensive private investment is required to deploy broadband networks, but that those networks will necessarily be open at the application layer in order for the investors to realize the benefits of network externalities.¹⁷⁸

Defining Packet Based Services

A proposed definition of packet based services for the purposes of deregulation is:

¹⁷⁷ Based upon the OSI seven layer reference model, the packet based transport services described here can be considered to include the physical, data link, network, and transport layers. The upper three layers in the OSI model; session, presentation, and application, can be considered, for the purposes of this discussion to be part of the end-user application or service.

¹⁷⁸ The migration away from private services, such as those offered by America On Line and Compuserve, towards public services such as Internet web site access and Internet e-mail, clearly demonstrate the incentives global network externalities offer.

Packet based local loop services shall mean all advanced telecommunications services provided using packet or cell based transmissions, over any transmission media, between a central office, head end, point of presence, or equivalent central facility, and packet or cell based terminating and origination equipment at a subscriber location where the packet based nature of the transmission permits routing of the packet or cell based on addressing information contained within said packet or cell, and wherein the peak data rate supported is no less than x Mb/s in the central facility to subscriber direction and y Mb/s in the subscriber to central facility direction.

The variables x and y in this definition would be set to ensure that the deregulated network is of sufficient capacity to ensure that the services offered are indeed broadband, and not just packet substitutes of the narrowband services (e.g. POTs over low-speed Internet connections). As an initial proposal, the downstream direction rate (x) is envisioned to be 1.5 Mb/s and the upstream direction (y) 384 kb/s.

It is likely to be necessary to put lower limits on the average data rates to preclude systems which can support high peak data rates to an individual subscriber at the expense of the rest of the subscribers on the network. Such systems could qualify for the deregulatory advantage but would not provide high bandwidth to all subscribers simultaneously. As an example, it is entirely possible to have a wireless or CATV system in which it is theoretically possible to give 6 Mb/s to one individual subscriber at the expense of the rest of the subscribers. At an extreme this would mean that a broadcast type infrastructure which serves 500 subscribers with one 6 Mb/s downstream channel and one 1.5 Mb/s upstream channel could be entirely unregulated. The additional restriction on the average data rate would ensure that the system is sufficiently broadband, or in economic terms, that there has been a substantial investment per subscriber.¹⁷⁹ The additional restrictions would be:

¹⁷⁹ Two-way cable systems are the best example of systems which can be incrementally upgraded to provide broadband services to a limited number of subscribers. A two-way cable plant based on Hybrid Fiber Coaxial (HFC) technology

...and wherein the average data rate supported to all subscribers connected to the network is no less than 384 kb/s in the central facility to subscriber direction and 128 kb/s in the subscriber to central facility direction.

Further restrictions on existing services would keep existing regulated packet services (e.g. frame relay) from becoming deregulated:

Such provisions shall not apply to existing Title II data services.

To see how such a definition would work in practice it is necessary to look at some practical situations in which both packet based and circuit switched equipment is employed. Fig. 3(a) illustrates a system in which services are provided in the local loop using a cell based format, which in this case is an ATM transport system. Even when the service is routed to a Time Division Multiplexed (TDM) circuit switch the local loop service itself remains packet based. If such a service met the given definition it would be exempt from regulation. Since the deregulatory effect is intended for the local loop, the format of the routing of the information on the backbone network has not effect on the definition of the local loop packet service.

Fig. 3(b) illustrates cases in which packet service providers lease or own local loop facilities, as well as the case in which the packet service provider leases bandwidth through a TDM circuit switch. In the case of leasing bandwidth, the service is exempt from regulation when the specified data rates are met. Similarly, if the service is provided by direct interconnection through leased or

can support "cable modems" for Internet access, once a small amount of additional equipment is placed at the head-end, and modems distributed to the subscribers. However, if the penetration rates become significant (e.g. over 20%) substantial investment in the plant (to reduce the node size) and at the head-end (for multiplexing and encryption equipment) is required. Once the penetration rate rises above a certain level, it becomes more cost effective to have a telephone type "switched" infrastructure in place. For a discussion of the costs of HFC vs. switched digital infrastructures see N. Omoigui, M.A. Sirbu, C. Eldering and N. Himayat, "Comparing integrated broadband architectures from an economic and public policy perspective," in *The Internet and Telecommunications Policy* (G. Brock and G. Rosston, eds., Lawrence Erlbaum Associates, Mahwah, NJ, 1995).

owned local loop facilities it would also be exempt from regulation when the specified data rates are met.

The conclusion that can be drawn is that when a containment philosophy is applied to the local loop, separation of packet based services from circuit switched services is possible, even if there are circuit switched elements in the rest of the network. There are clearly numerous other issues related to deregulation of the backbone network which are not dealt with here, but which can be addressed separately.